# Analysis of Bluefin Tuna and Menhaden Schools From Images Collected From Small UAS

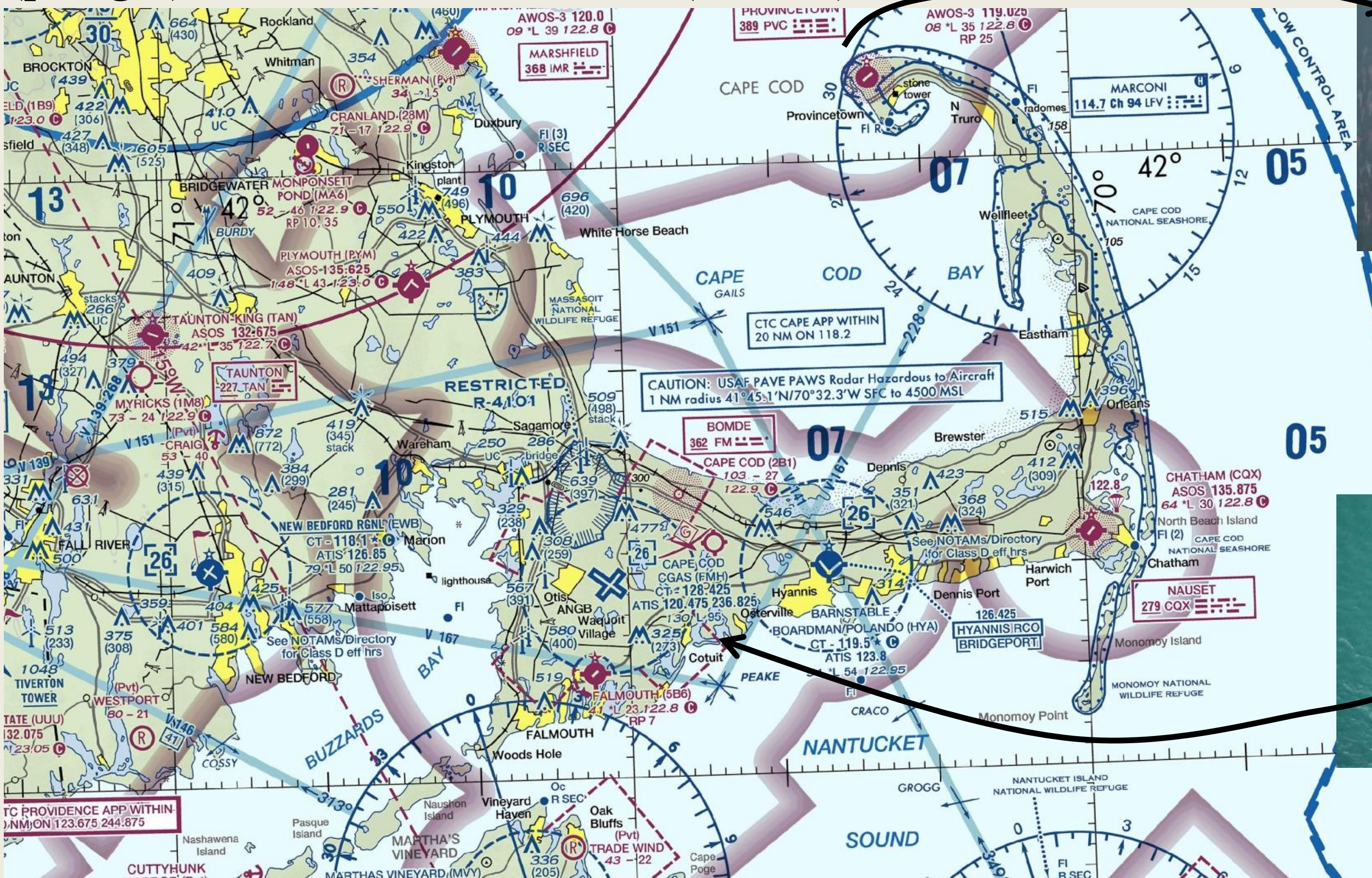

- Mike Jech, NOAA NEFSC
- Molly Lutcavage, LPRC, UMass-Boston
- Jennifer Johnson, Integrated Statistics
- Angelia Vanderlaan, Canadian DFO
- Yuri Rzhanov, CCOM, UNH
- Tom Weber, CCOM, UNH
- Serdar Sakinan, WHOI
- Ray Mroch, NOAA SEFSC
- Don LeRoi, Aerial Imaging Solutions



•**Special thanks to Bill Muniz (F/V Lily) and Mark Brochu (spotter pilot)**

The goal is to estimate stock/population abundance of pelagic fish species, especially species that spend some time at the sea surface or in shallow areas (e.g., estuaries), making them difficult to sample with traditional nets and hull-mounted, downward-looking acoustics.

Two species selected for pilot projects: juvenile Atlantic bluefin tuna (ABFT) (pelagic) and Atlantic menhaden (coastal)




**Objectives of pilot projects are:**

- Evaluate aerial imagery for quantitative measures of fish schools and individual attributes (ID, size, behavior)
- Evaluate “horizontally-looking” acoustic measures of fish schools and individual attributes
- Combine optical and acoustic data to estimate abundance and biomass for each school
- “Scale up” from single schools to regional estimates of stock abundance and biomass

**Data**

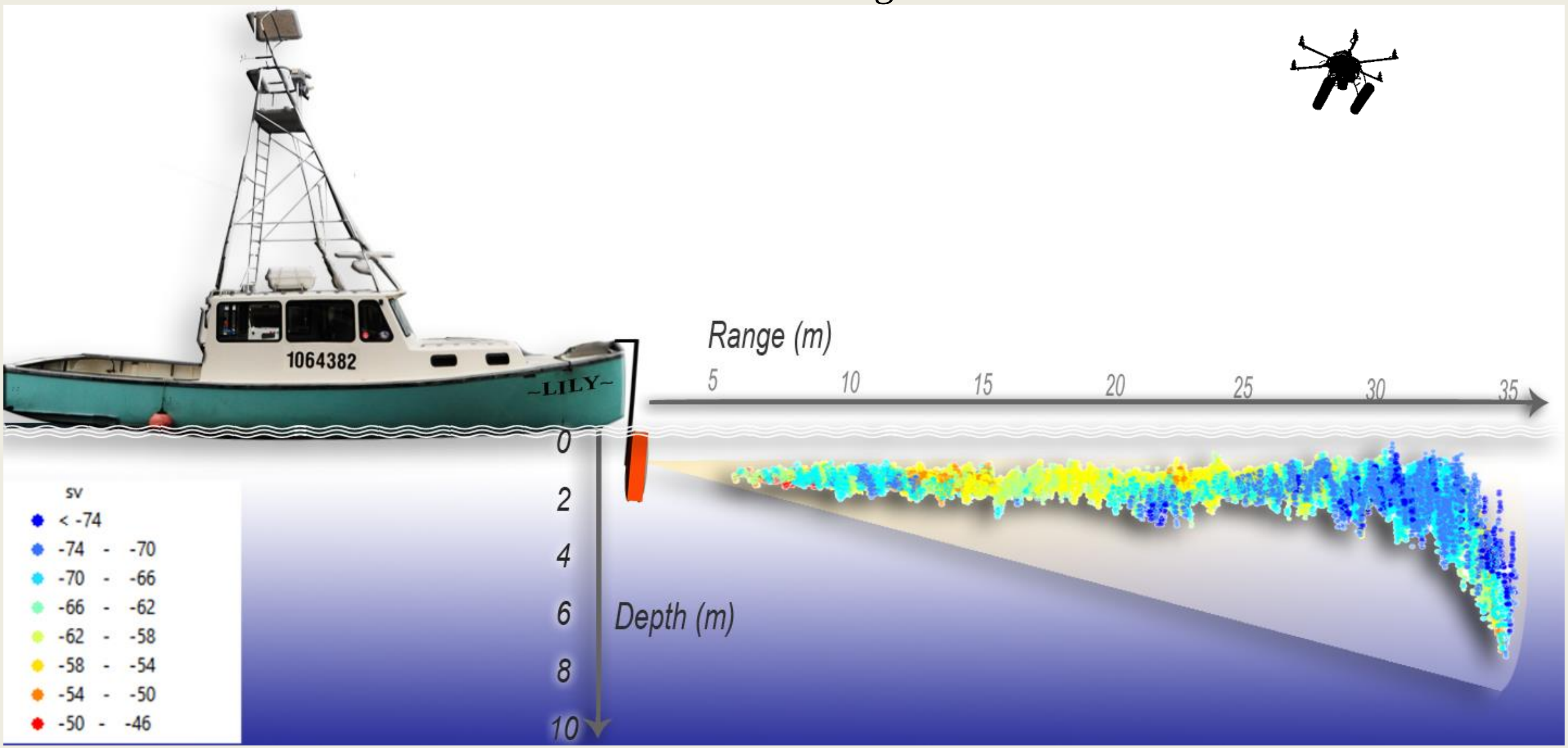
- 2015
  - Flights over ABFT near Provincetown, MA
  - Flights and acoustics on menhaden in Woods Hole, MA
- 2016
  - Flights and acoustics on menhaden along MA coastline

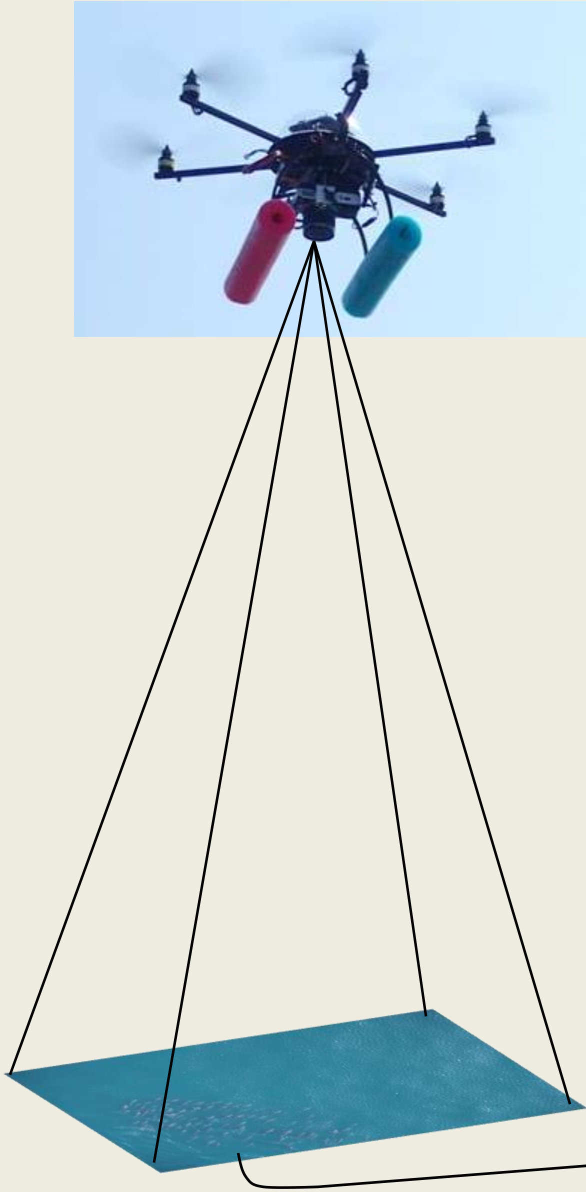
There were many different permutations of lenses, camera settings, gimbal/no gimbal, potential altitude bias, so we won’t get into all the gory details of data processing, but we present preliminary analyses to highlight progress and “lessons learned”.

## Acoustic Data:

- Evaluate ability of horizontally-oriented sonar to detect, measure “underwater” distribution (vertical and horizontal extent), and potentially enumerate fish near the surface.

- Schematic of the F/V Lily and acoustic split-beam transducer showing the vertical and range-dependent volume backscattering strength (Sv, dB) of a menhaden school (aerial image shown later). Using split-beam we can measure spatial distribution of the school to match with aerial images.





UAS Platform – Engineering, Physics

- Design and development
- Software (e.g., flight control, sensor integration) development
- Sensors – e.g.,
  - motion (pitch, roll, heading),
  - altitude (pressure or GPS),
  - position (GPS)

Optics – Engineering, Physics

- Camera technology (e.g., sensor, lens)
- Light & color

Image Processing & Analysis – Mathematics, Computer Science

- Detection
- Identification
- Measurement
- Automation

Biology!

- Size & abundance & distribution
- Management & conservation
- Condition of stock & individuals
- Behavior

## Scientific Requirements for Aerial Imagery

1. Quantitative, repeatable, and consistent measurements
2. Length measurements to sub-cm precision
3. Aerial images of entire school

Compromises between 2 & 3 (i.e., “zoom in” vs wide angle), and among species (larger species need less precision)?

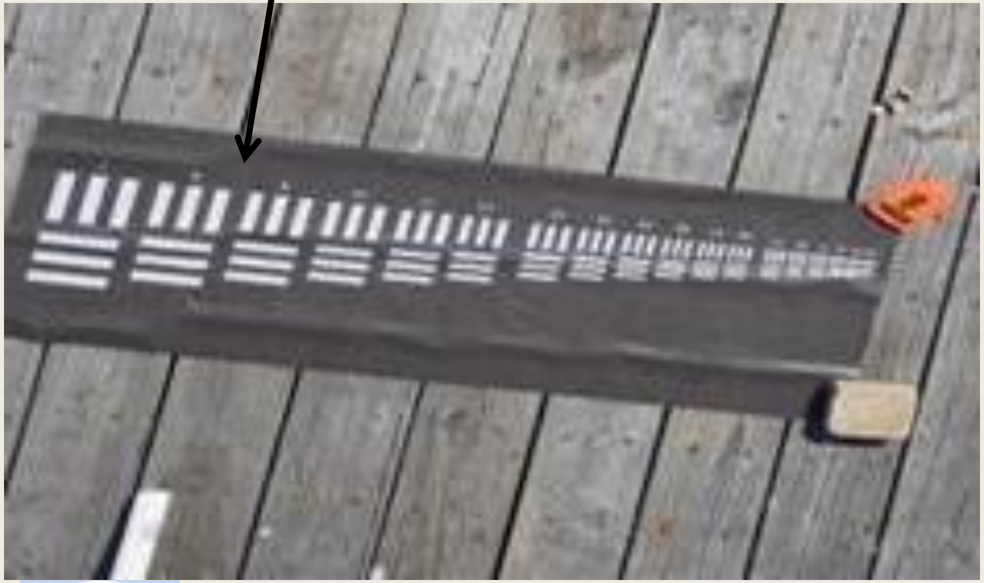
## UAS Platform – APH-22

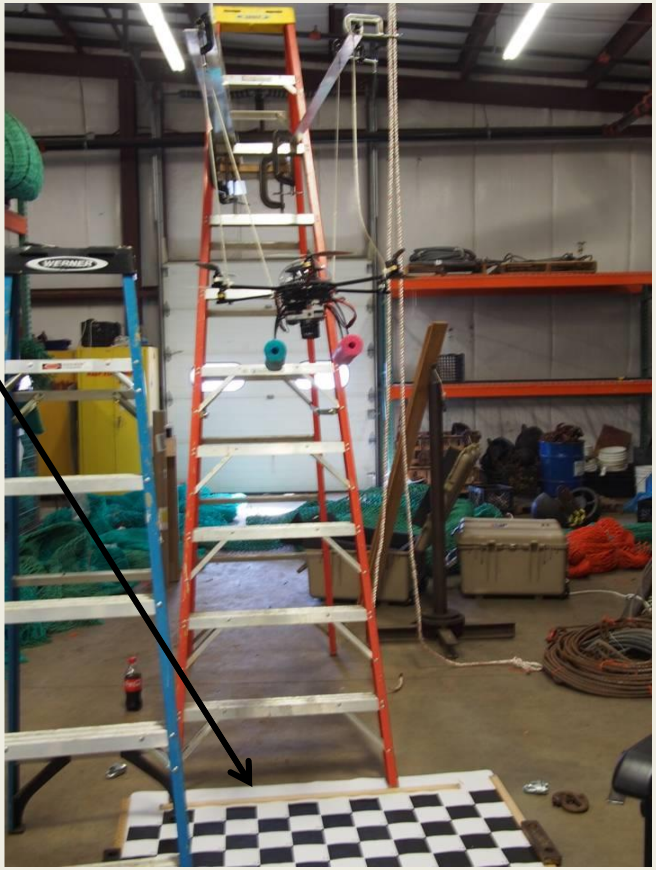
- Multirotor (hexacopter) vertical take off and landing (VTOL) developed and built by Aerial Imaging Solutions
- Sensors
  - motion (pitch, roll, heading),
  - altitude (pressure or GPS),
  - position (GPS)
  - Recorded to ASCII file during flight (GPX file)
- Olympus E-PM2 digital camera
  - 20 or 25 mm fixed focal length lens
  - Video feed for real-time feedback from camera
  - Digital still images (4608x3456 pixels) for analysis
    - 1-4 s interval recorded on camera’s SD card

# “To Do” List

Things to do before you start measuring fish or other targets of interest

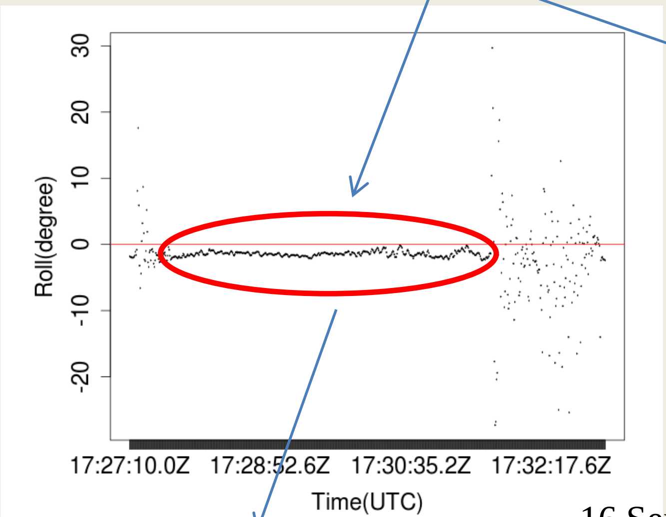
- Calibrate the camera and lens. Need to do at least once, and then routine checks.
- Calibrate or assess accuracy and precision of sensors (motion, altitude, location, …). Need to do at least once, and then routine checks.
- Confirm parameter settings and measurements using resolution chart or objects of known size. **Do every flight**!

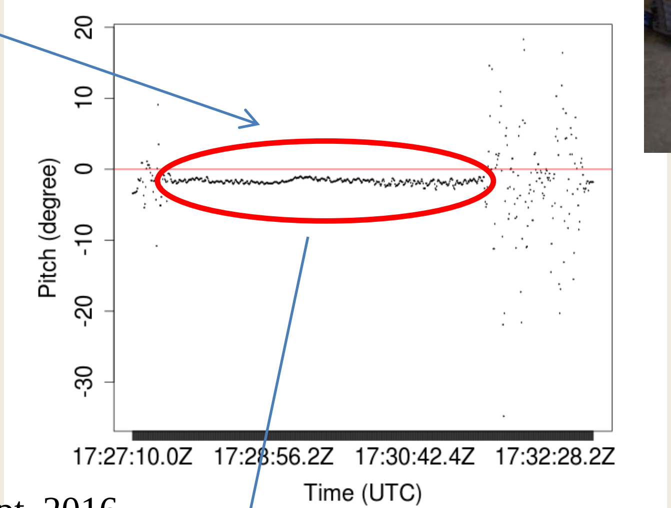




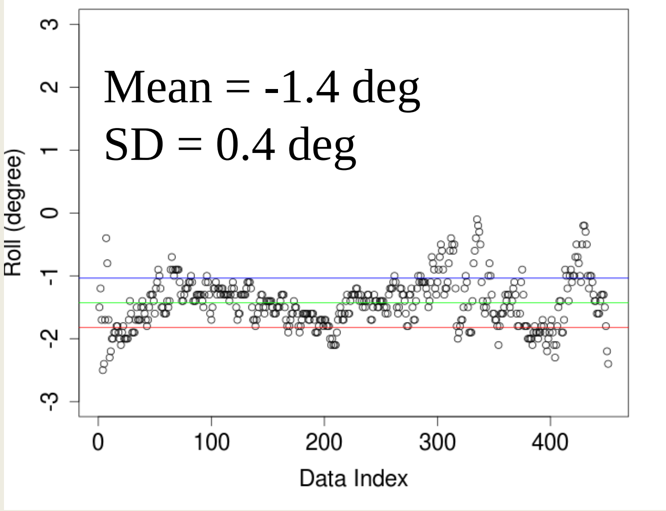
# APH-22 Sensor Evaluation

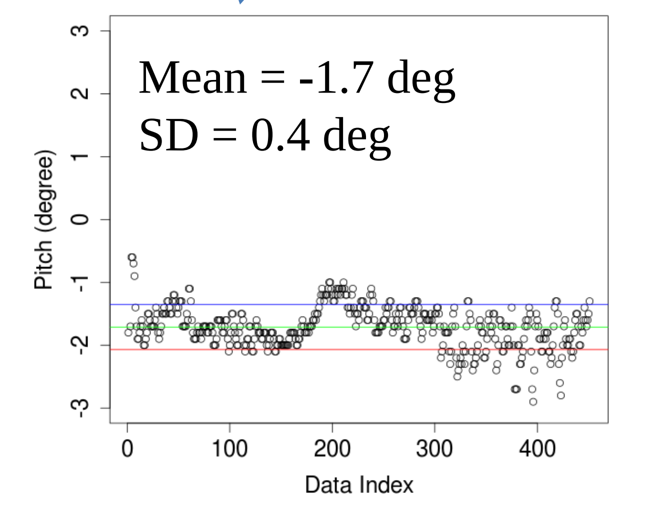
- Sensors
    - motion **(pitch, roll**, heading)
    - Apparent bias/offset in pitch and roll during flights over menhaden schools at the NEFSC dock in calm/low winds




16 Sept. 2016



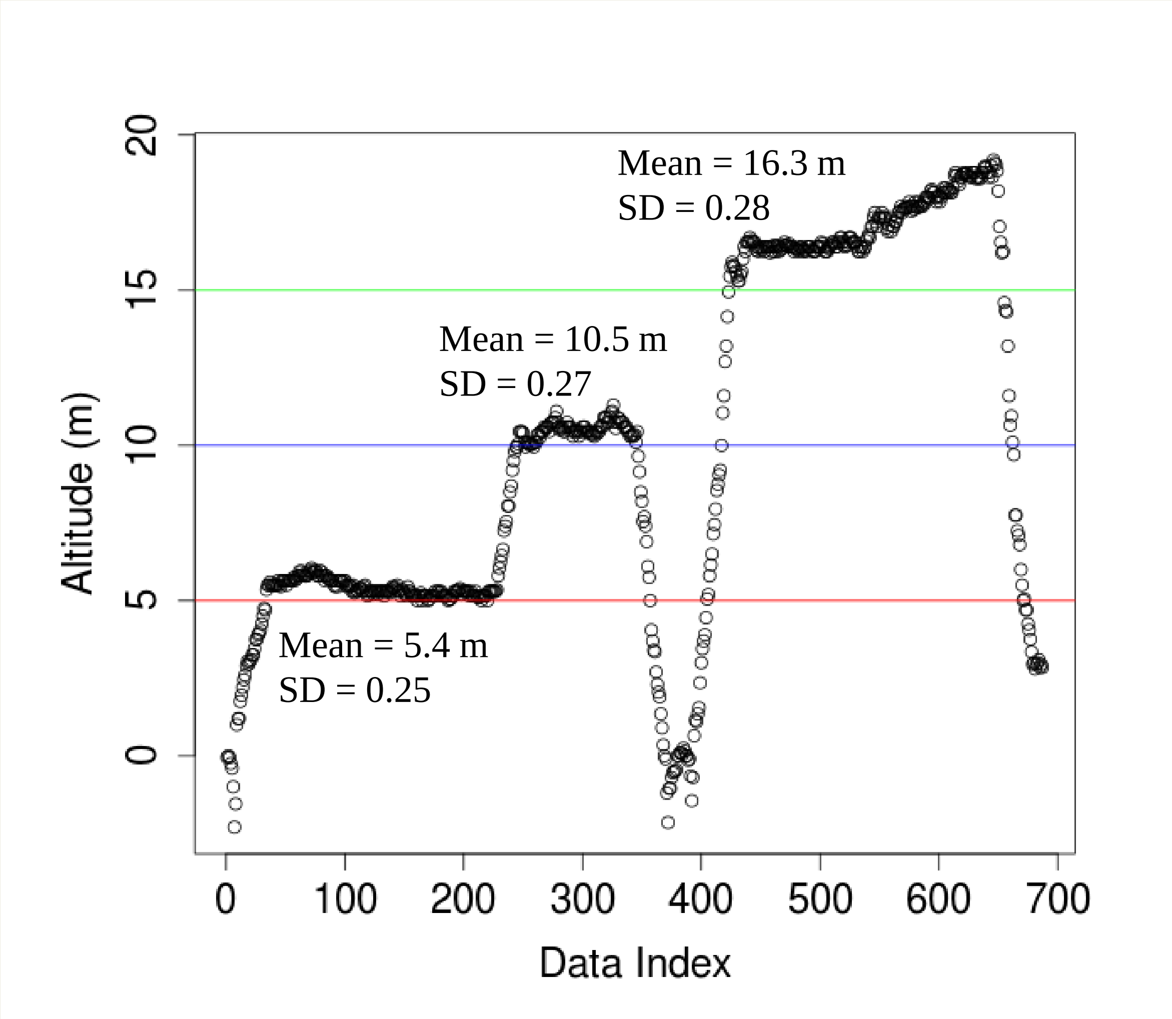

## Pitch & Roll Evaluation

- Placed APH-22 on Al plate with 2D inclinometer @ 0.1° precision
- When we calibrated to 0.0°, the pitch and roll recorded 0.0°
- When we inclined the plate to 0.x$^0$, pitch and roll recorded to 0.x°, with "jitter" of 0.1°
- Offset/bias is most likely due to
    - Wind
    - Initial cal with bubble level

- HOWEVER, the camera is now mounted to a gimbal. This should eliminate, or at least minimize motion compensation.

# APH-22 Sensor Evaluation

- Sensors
  - altitude (**pressure** or GPS)




## Altitude Evaluation

- Affixed a measuring tape to the APH-22 with “zero” near the camera lens.
- While the measuring tape was held to the ground at 5, 10, and 15 m altitude, the APH-22 was flown to keep tension on the measuring tape
- Difference in recorded vs. known altitudes showed a 5-10% error in recorded altitude.
- Cause(s) of differences is/are unknown.
  - Different atmospheric conditions
  - Pressure sensor  is not sensitive enough
  - Translation from pressure to altitude
  - Even larger discrepancies are noticed with recent firmware version and/or new sensors.
  - Are “errors” consistent?
  - (more later)

Juvenile Atlantic bluefin tuna (ABFT) and Atlantic menhaden measurements

There were many different permutations of lenses, camera settings, gimbal/no gimbal, potential altitude bias, so we won't get into all the gory details of data processing.

- 2015
    - Flights over ABFT near Provincetown, MA
    - Flights over menhaden in Woods Hole, MA
- 2016
    - Flights over menhaden along MA coastline

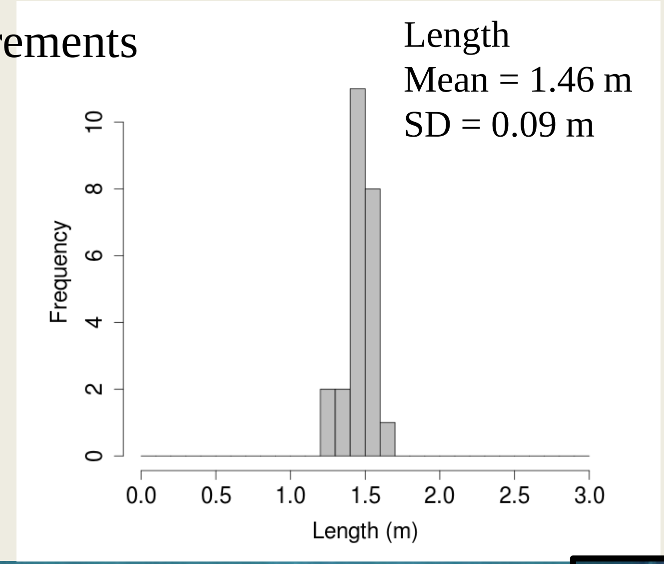
- We present some preliminary analysis to highlight progress

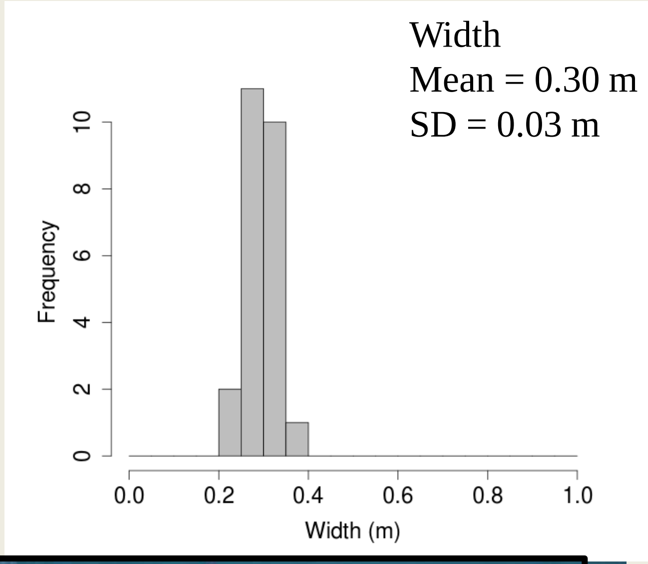
# Atlantic Bluefin Tuna Measurements

Two days of flights in Sept. 2016

- Length
- Width
- Nearest-Neighbor Distance

Mean = 2.1 m
SD = 0.62 m



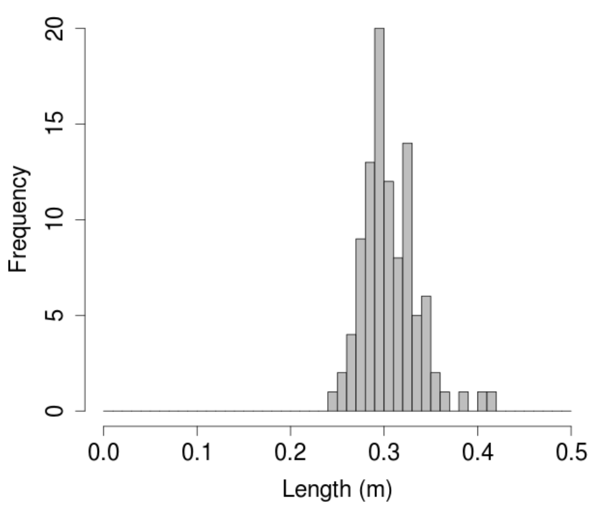

# Menhaden Schools & Individuals, and Predators!

Nearest Neighbor Distance:
Mean = 0.18 m
SD = 0.05 m

School Area: 120.5 $m^2$

Predator length range:
0.46 – 0.75 m.
Striped bass (*Morone saxatilis*)?

Menhaden length frequency
("standard" length)





## Discussion Topics

The APH-22 hardware and software are evolving, as well as the image analysis software and procedures. Many of the procedures we've developed to measure fish will not be needed as instruments and software evolve.

- Implementation of the gimbal for the camera should eliminate or at least minimize motion compensation – but we need to measure and assess gimbal performance
- Altitude is potentially largest contributor to error and altitude data are based on pressure sensor.
    - Implementing a laser altimeter. Will it work over water? If not, can we use it to calibrate the pressure sensor for each flight?
- Our image processing is manual, but are looking into more automated software, such as "Habcam" (habitat camera) annotation and measurement software.
- ID of targets. We have images with confirmed ABFT and menhaden, but think we have images of striped bass and blue fish (*Pomatomus saltatrix*). We need to work through visual ID, then automated ID.
- Sampling/survey design. How do we "scale up" from single schools to regional estimates? Will VTOL be sufficient, or do we need fixed wing UAS? Currently, we <u>need</u> a spotter pilot!
- Always get an image of a known-sized object! Resolution chart is best, but something on the boat or launch/recovery area is good too.